Evidences of
Sedimentation Rhythms

Storm

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EVIDENCES OF SEDIMENTATION RHYTHMS IN THE SHENANDOAH LIMESTONE NEAR IVY ROCK, MONTGOMERY COUNTY, PENNSYLVANIA.

A thesis presented to the faculty of the Graduate School of the University of Pennsylvania, in partial fulfillment of the requirements for the degree of Master of Science.

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INTRODUCTION.

SEDIMENTATION AND SEDIMENTATION RHYTHMS.

A sedimentary rock is identified by means of its bedding planes or laminae; either or both of these accompanying sandstones, shales, limestones, and often chemically precipitated sediments such as beds of gypsum or salt. Bedding planes or laminae in a rock show that while the rock was in the process of formation there was at times a cessation of deposition, and then a resumption of deposition after the lapse of a certain time interval.

Deposition may be resumed under conditions which differ much or little from the original conditions of deposition before the cessation. The material of the second layer may differ in size or mineral character from that of the first; or chemical composition of the layer may vary, so that later on differential weathering may bring out bands of contrasting color and prominence on the surface of the exposed rock. Changes in degree of saturation of a solution from which is being deposited such material as gypsum or salt, may result in banding, and likewise the presence of impurities in such a solution, together with change in degree of saturation; e.g. gypsum showing bands of limonite.

According to James Giekie, thin laminae mean slow accumulation and usually in quiet water. As a general rule coarse sediments accumulate faster than fine, and a homogeneous rock faster than a

banded rock. Giekie states that of two beds of similar characteristic thickest does not always take the longest time to accumulate.

Giekie, James. Structural and Field Geology. Chapter VI.

Bedding planes, whether they separate beds several feet thick or beds of paper thinness, represent a time interval during which no deposition was taking place. The bedding planes separating thin laminae represent a shorter time than do the bedding planes separating strata.

Giekie, James. Op. cit.

Shallow water accumulations show rapid alternation in size of particles, and we infer that it took only a short time for each layer to accumulate. Fine material implies deeper water and slower accumulation. It is justifiable to infer that planes of stratification among fine accumulations represent longer time intervals than in the case of estuarine and littoral deposits.

Should a pure marine limestone stratum lie between strata of thick argillaceous shales, it could be assumed that the bedding planes indicated lengthy intervals of time. The succession of strata would indicate a change from mud depositing conditions to lime depositing conditions and back again. It is stated that bedding planes may often represent longer periods of time than the strata which they separate.

Giekie, James . Op. cit.

Conditions resembling those described in the preceding paragraph are visible in the Shenandoah limestone in the district covered by this investigation, and will be discussed in detail later. Some of the argillaceous layers in the Shenandoah limestone are separated by a considerable thickness of limetone beds, and in other instances both limestone and argilaceous layers are very thin.

The rate of accumulation of sediments was formerly regarded as dependent on the type of sediment, fine sediments being considered to accumulate more slowly than coarse ones. Factors affecting this principle, along with very complete discussion of the significance of bedding planes and of banding, are set forth in Barrell's "Rhythms and the Measurement of Geologic Time".

Barrell, Joseph. Rhythms and the Measurements of Geologic Time.
Bull. Geol. Soc. Am., Vol. 28, pp. 754-904.

Barrell says, "The sediments whose interpretation form the basis of earth history have been characteristically deposited with respect to a nearly horizontal controlling surface. This surface of control is base-level, but for continental and marine deposits the base-level is determined by different agencies and is a word of more inclusive content than the sense in which it has generally been used by physiographers as a level limiting the depth of fluviatile erosion. Sedimentation as well as erosion is controlled by base-level, and base-level, local or regional, is the surface toward which the external forces strive, the surface at which neither sedimentation nor erosion takes place".

Deposition, according to Barrell, is dependent on upward oscillations of base-level or downward oscillations of the bottom, either of which makes room for sediments below base-level. Hence the control rate of vertical thickening of beds is something less than the rate of supply of sediment, and the balance of sediment is carried further by agents of transportation. The storage for the final excess, except for certain local deep land waters, is on the abyssal slopes of the continental platforms, and lost to observation.

Thus sedimentation is usually controlled by base-level rather than by rate of supply of sediment. Control of base-level in turn depends upon the rate of discontinuous depression of the surface of deposition. Sedimentation is the effect of depression to a greater extent than it is the cause."

Barrell, Joseph. Op. cit.

Base-level, mentioned in connection with deposition of sediment in marine waters, refers to wave-base, and Barrell defines wave-base as that depth at which the wave action ceases to be strong enough to transport sediment. If the wave action becomes strong the particles of sediment are moved with the oscillations of each wave, and affected by currents, undertow, etc., but the particles will move in a direction determined by the resultant of these forces. An increase in the strength of the waves brings about down-scouring of the bottom and a removal of material to deeper water, especially the finer material. The coarsest may be moved toward the shore as sand or shingle.

The carrying of material by the stirring of currents or oscillations of waves, is not, according to Barrell, a continuous process, even in areas of crustal depression, but represents an irregularly rhythmic alternation of fill and scour with the balance in favor of the fill.

Rhythmic deposition of sediments may result from other causes than the alternation of fill and scour described in the preceding paragraph, which depend on oscilations of the base-level or of the wave-base.

For example, rhythmic banding may be seen in such chemically-formed sediments as gypsum, where changing concentration of the solution causes supersaturation and deposition, undersaturation, and non-deposition. We may also have the gradation of one layer into another, which

may represent continuous deposition, but with changing rates.

Barrell, Joseph. Op. cit.

Banding, of a more or less rhythmic nature, is seen in certain mineral groups, especially in chalcedony, agate, opal, etc. This is probably due to physico-chemical action, and has been duplicated in the laboratory by allowing crystals of varius substances to form in a solution of sodium silicate gel. The crystals arranged themselves in a rhythmic pattern showing alternations of bands of crystals with bands of the clear gel. Could this action ever take place on a large enough scale to produce banding in a rock formation ?

The rhythmic nature of all banding in rocks, whether in chemically or mechanically deposited sediments, may, in the present state of our knowledge, be traced back to diastrophic movement, or climatic variation, or to a combination of these causes.

Diastrophic movements which result in uplift of a land area and increase the erosion rate, would, of course, increase the amount of sediment carried by streams.

But according to Barrell's principle, the increase of sediment alone would not of necessity result in thick beds, but thick beds would result from the greater depression of the base-level (wave-base) in the epicontinental sea where the material was being deposited. Diastrophic movement would result in rhythms of a very broad nature, extending over very long periods of time, and having superimposed on them many minor rhythms, due to climatic changes, which in turn might be of several kinds, such as seasonal, cyclic, and mere local storms.

Seasonal climatic changes may produce abundant during part of the year and less sediment during the remainder, when precipitation is less. This may, and in some cases, has, left a distinct and traceable record in a sedimentary deposit. One of the best examples is in the banding of glacial clays, deposited in water which resulted from the melting of the ice. Such water during the summer season brought down much sediment, and coarser sediment, while the winter sediment was less in quantity and finer. By tracing out the summer and winter layers in some of the glacially-deposited sediments of New England Antevs has been able to work out the amount of time in years since the melting of the Pleistocene ice sheet began. DeGeer has done the same in Sweden.

Antevs, Ernst. The Retreat of the Ice Sheet in New England.

Certain layers in the Shenandoah limestone of the Ivy Rock district show alternating laminae, consisting of limestone and phyllite, each lamination being so thin (less than 1/8" in many cases) that they suggested seasonal climatic variation to the writer, as a possible cause for them, since their extreme thinness suggests that they might accumulate in a few months.

Rhythmic alternations of laminae may also be due to local storms which cause the formation of larger waves with a consequent lowering of the wave-base and a temporary increase in thickness and coarseness of sediment. This is followed by the return to normal thinness and fine-grained layers for that locality.

Climatic changes, as indicated by the records in the rocks, may also be changes of a cyclic nature, spread over a long period, hundreds or even thousands of years. Superimposed on this grand climatic cycle there

may be evidence of minor cycles.

Barrell observed such evidences in the marine mudstones composing the Martinsburg or Hudson River slates in the Lehigh Valley of Pennsylvania. These slates have a finely-banded or"ribboned" structure,and after detailed study of the layers Barrell makes the following statement concerning them:-

These ribboned slates indicate at recurring intervals the stirring up of the bottom of a shallow Ordovician sea by waves of unusual intensity. On the dying down of the wave action the sediments held in the water at that place settled,making a ribbon of this character. Some of the sediment was carried away by the waves. The width of the ribbon represents merely what settled from the water on the subsidence of the storm. During the storm sediment was scoured out and worked to localities of deeper and quieter water. Rhythmic intensification of this action resulted in an alternation of fill and scour in which the surface of sedimentation was raised and depressed by changing intensity of wave action.

Barrell,Joseph. Op. cit.

An indirect result of climatic change is brought about in sediments by the smothering with mud of colonies of lime-secreting organisms such as cryptozoa. This was also observed by Barrell in Lower Ordovician limestone near Allentown,Pennsylvania. Barrell believes that the cryptozoa had been periodically blanketed with mud,following which new cryptozoan colonies would start on top of the layers of mud. The mud was of a limey nature. The strong wave action and influx of mud formed layers of dark gray limestone; gentler wave action and

clear water permitted growth of cryptozoa, and formed a limestone layer easily distinguishable from the dark gray limey-mud layer. These conditions alternated in a markedly rhythmic fashion. Many fine laminae make up a minor rhythm. Four or five minor rhythms lead up to a crescendo favoring a progressively longer time for the growth of cryptozoa. Then there was a sudden change to the lime-mud phase. Barrell states that the sudden change in the character of the rhythm may mean a loss of record.

Barrell, Joseph. Op. cit.

Coagulation of sediments of colloidal fineness by salt waters may produce rhythmic alternations of layers. E.M. Kindle has shown how to produce this effect experimentally. Silt, stirred up in fresh water, deposits the coarse particles first. In salt water the finest silt coagulates first and then the fine sand is deposited on top of the coagulated material.

Kindle, E.M. Diagnostic Characteristics of Marine Clastics.
Presented before Geological Soc. Am. Dec. 29, 1916.

Climatic changes or other agents might bring about changes in the salt concentration of sea water for a given locality, and this in turn might give rise to a banded structure in the sediments deposited on the bottom of the sea.

According to Barrell the rhythms in nature are composite ; many minor rhythms superimposed on a few major rhythms. He suggests the possibility of the history of climatic fluctuations being locked up in the sedimentary rocks, and also the possibility of the sun's temperature changes in the past being worked out by a study of the rocks.

THE SHENANDOAH LIMESTONE.

The purpose of this investigation is to determine the presence or absence of sedimentation rhythms in the Shenandoah limestone. The term "Shenandoah" as used in the Philadelphia Folio area (Folio 3,U.S. G.S.) is applied to a series of heavily bedded ,crystalline,white or blue magnesian limestone,with phyllite layers,and also with some highly siliceous members. Both the silica and magnesia content vary considerably,but in no case is the magnesia content high enough to warrant calling the formation a dolomite.

Philadelphia,Folio. U.S. Geological Survey.

The rock is everywhere crystalline and in some places very micaceous,thin layers of phyllite being intercalated with layers of limestone. In some places in the Ivy Rock district(dealt with in this investigation) the micaceous layers are solid phyllite,and very thin, from 1/16" to about 1/8". In ~~an~~ another part of the Ivy Rock district a phyllite layer 4 inches thick was found,and in still another place one 4 inches thick. These very thick layers are an exception; most of the phyllite layers are around 1/8" in thickness. Some of the beds in this district take on the character of a calcareous and micaceous schist. These phases of the Shenandoah formation will be discussed in more detail later,since it is by means of the micaceous layers that the evidences of sedimentation rhythms were determined.

The following analysis of Shenandoah limestone from West Conshohocken,Pa.,is given in the Philadelphia Folio of the U.S. Geological Survey:

SiO_2	24.[illegible]
Al_2O_3	1.10
Fe_2O_3	1.50
MgO	.11
CaO	.55
Alkalies	1.42
$CaCO_3$	4[illegible].77
$MgCO_3$	31.74
	100.00

GEOLOGIC STRUCTURE OF THE SHENANDOAH LIMESTONE IN THE PHILADELPHIA FOLIO AREA.

The Shenandoah formation in the Philadelphia district lies above the Cambrian(Chickies) quartzite in an unsymmetrical syncline. The prevailing strike is N. 60 to 90 degrees E. and the dips vary from 35 to 85 degrees S.E. with a gradual change in the average strike and dip around the end of the synclinal trough which occupies the northeastern end of Chester Valley.

Philadelphia Folio. U.S. Geological Survey.

Isoclinal folds are common in the formation, and structural evidence of one was observed in the north end of "Rifle Range" Quarry. (See Figure 1). One reversed fault was observed in the east face of the "North" Quarry, and some distorted and folded beds are evident in the west face of the Lukens and Yerkes quarry mentioned further on in this paper. The total thickness of the Shenandoah formation is given in the Philadelphia Folio as not greater than 1,[illegible] feet.

AGE OF THE SHENANDOAH FORMATION.

The geologic age of the Shenandoah formation is given in the Philadelphia Folio as Cambro-Ordovician. Ordovician fossils of Chazy, Beekmantown, and Trenton age have been found to the west of Chester Valley, and this, together with the fact that the limestone overlies conformably Georgian (Lower Cambrian) quartzite, has resulted in placing the Shenandoah as Cambro-Ordovician. This limestone of the Philadelphia region is correlated with the Stockbridge limestone of New England and New York, doubtfully with the Cockeysville marble of Maryland, and with the limestone of the Shenandoah Valley, Virginia, whence the formation receives its name.

Philadelphia Folio. U.S. Geological Survey.

GENERAL CONDITIONS IN THE EASTERN UNITED STATES DURING ORDOVICIAN TIME.

General conditions existing in the eastern United States during the Ordovician period are described by Chamberlin and Salisbury as follows:

Along the western base of the elongate tract of land in the eastern United States (Appalachia) mud, sand, and gravel washed down from the land were being deposited. In general the coarser materials were left nearer the land, while the finer were carried farther out. Alternating beds of coarse and fine sediment may indicate either that the adjoining land was higher at some times than at others, or that the climatic conditions or the vegetable covering changed, or that the

waves and currents varied in their strength.

Along the belt where the Appalachian mountain system was to appear later, limestone, the product of clear waters, is very subordinate to clastic rocks among the formations of the Ordovician system.

Chamberlin and Salisbury. Geology. Vol. II.

The above generalized description is applied to the Ordovician system of Maryland and Pennsylvania as a whole, but could not be directly applied to the region dealt with by this investigation. In the Ivy Rock district the limestone-dolomite phase of the Shenandoah predominates over the clastic sediments, although the limestone does here contain large amounts of clay sediment, and sometimes siliceous layers.

The Shenandoah limestone throughout this district, and also in neighboring districts in southeastern Pennsylvania, is quite crystalline. This fact, together with the presence of phyllite throughout the rock, and the tilted and folded attitude of the beds, indicates considerable dynamic metamorphism.

The cause of the metamorphism observed in the early Paleozoic limestones of southeastern Pennsylvania has been generally assumed to be the Appalachian revolution. It may be questioned, however, from the nature of these limestones, whether this metamorphism may not represent an earlier disturbance, whose effect has been added to that produced by the Appalachian disturbance of Permian time. Possibly the Taconic revolution, at the close of the Ordovician, whose effects were widely distributed both east and west of the Mississippi, had some effect in bringing about the present highly crystalline condition of the formation. The highlytilted beds, and the folding suggest the prolonged action of powerful dynamic forces.

THE SHENANDOAH LIMESTONE OF THE IVY ROCK DISTRICT AND ITS SEDIMENTATION PHENOMENA.

The territory covered by this investigation lies between Conshohocken and Norristown, Montgomery County, Pennsylvania, and is a part of the Norristown quadrangle of the U.S. Geological Survey, and is described in detail in the Philadelphia Folio. The nearest railway station is Ivy Rock, on the Schuylkill division of the Pennsylvania Railroad. (See map, Figure 2)

Three quarries were examined; of these, two were in a direct line, north and south, and not more than [illegible] feet apart; the third was north and a little east of these two, and a little less than half a mile distant. A North-South line connecting the two quarries mentioned first would be a line at approximately right angles to the strike of the Shenandoah limestone, and the third quarry lies but a few hundred feet to the east of this line.

Northernmost quarry is now being worked, and is known as the Lukens and Yerkes quarry; the next one to the south will be called for convenience the "North" Quarry, and the southernmost one the "Rifle Range" Quarry. These quarries and their distribution in the Ivy Rock district are shown in Figure 2, appended to this report. The dip and strike are about the same in all three localities. Locally, in two or three places, the dip increases sharply, due to a minor fold, but it quickly changes back to the average dip of the region, which is between 25 and 30 degrees, and in a direction slightly east of south. The general strike in the Ivy Rock district is about east and west; the line passes a little to the N.E. and little to the S.W., but only a few degrees from the true east-west position.

Three determinations of dip in the Lukens and Yerkes Quarry gave 55 degrees, 57 degrees, and 37 degrees respectively. Two determina tions in the Rifle Range Quarry gave 45 degrees and [illegible] degrees. Slightly under 50 degrees seems a fair average for the district.

The tilting of the Shenandoah beds has already been mentioned. Accompanying this tilting there was minor and localized folding and faulting, and probably many instances of isoclinal folding. (see Figure 1). The tops of the isoclinal folds have since been eroded away, and the presence of the folds, lacking fossils, can only be told by careful study of the succession of strata, and of repitition of a given succession. Such an isoclinal fold is suggest by the arrangement of the strata in a part of the west face of Rifle Range Quarry. (Figure 1). Although these isoclinal folds would give a false idea of the number of times a given rhythm or combination of rhythms was repeated, at the same time they would not nullify the fact that the original combination of rhythms occurred.

DESCRIPTION OF THE SHENANDOAH BEDS DISCUSSED IN THIS REPORT.

Within the limits of the three quarries already mentioned, several types of rock may be seen, and groups of beds were noticed which differed considerably in thickness and to some extent in lithologic character. These beds will be hereafter designated by appropriate symbols and referred to by their symbols, both in the body of this paper and in the accompanying figures.

Type "A" is a massive and heavily bedded gray crystalline limestone. Its hardness, which is greater than 3 in Moh's scale (3 is the approximate hardness of the average limestone) suggests a rather high silica content. There are, at intervals, irregularly occurring phyllite layers

in the "A" beds, but these layers are usually difficult to trace for any distance, and so uncertain that no data for sedimentation rhythms was based on the phyllite layers of these beds.

A variant of the "A" beds is the same rock lithologically and structurally, but possesses an irregular fracture, so that it breaks off in such a way as to leave the surface of the quarry well covered with minor irregularities, giving it the appearance of having been shattered by a heavy blast.

Blasting, however, cannot account for the fact that the shattered effect is spread evenly over the surface of the type "A" rock, that it does not appear on the other rock types observed, and that where seen, it is confined definitely within distinct limits. This shattered effect is probably due to dynamic metamorphism.

Type "A'" is massive limestone of the same lithologic character as type "A" but in this the bedding occurs in layers of from two to four inches thick. The bedding planes show a well-marked parallelism, and in the bedding planes are layers of phyllite of almost paper thinness, but very evident, and very persistent. For convenience the type "A'" limestone is included under the symbol "Z" in the diagram shown in figure 3.

Type "Z" is a thinly laminated limestone which exists in layers of from 1/2" to 1 1/2" in thickness, and these layers are separated by layers of phyllite which vary in thickness from less than 1/16" to about 1/4". A few phyllite layers are 1/2" thick. The limestone itself seems to be of the same lithologic character as type "A".

Contained within this type "Z" limestone are certain beds made up of regularly alternating layers of limestone and phyllite, of equal

of equal thickness, each layer, or lamination, being about 1/8" thick. These layers are so thin, and so regular, that they suggested to the writer the possibility of their being "seasonal" layers - that is the phyllite was formed from clay which came into the Shenandoah sea in relatively larger quantities during every wet season when the forces of erosion erosion acting on the ancient land surface were more vigorous.

No attempt has yet been made by the writer to work out a cycle of sedimentation rhythms using these layers as a basis, because of the mechanical difficulty involved in the time allotted for this research. These layers are designated on the diagrams in figure 3 by the letter "Y".

Solid layers of phyllite were noted in all three quarries, which were thicker than most of the phyllite partings in the limestone. These thick layers of phyllite varied from 1/2" to as much as 4", although only one of this thickness was noted. They thicken and thin as they are followed up and down the quarry face. None of these layers happened to occur in the section of the Rifle Range Quarry in which the data for figure 3 were obtained ; therefore they fo not appear in figure 3.

Besides the types of rock which are designated by letters there are minor variations which are not persistent or prominent enough to be given a type letter in this scheme of classification. In the North Quarry there is a thirteen foot layer of highly siliceous iron-stained rock, and this has limonite concretions scattered through it. These concretions are from about 3" to 12" in diameter, and were visible on the west wall of the quarry only. Iron stains were prominent on the east face, but no actual concretions were seen at the surface. This

condition was probably caused by the covering up of the concretions on the east quarry face by soil and rock which have washed down from the top of the quarry.

Another layer of highly siliceous limestone occurs next to the concretion layer, but differs from it in having no concretions, although it, too, is iron-stained, and also differs in having a prominent laminated structure, the laminations being from 1/2 to 2 or 3" thick. Siliceous layers are not uncommon in the Shenandoah limestone of the Philadelphia region, and they have not been as yet especially considered in connection with sedimentation rhythms.

THE RHYTHMS EVIDENT IN THE IVY ROCK DISTRICT.

A glance at figure 3 accompanying this report will show something of the rhythmic succession of different types of layers, and of limestone and phyllite layers. Figure 3 is based on detailed work in the north end of Rifle Range Quarry; the total thickness measured in detail was about 60 feet. The rhythms shown in figure 3 are, therefore, only only a part of the succession of rhythms observed in the district, but enough is shown to give an idea of the rhythmic succession of layers.

It is quite probable that more extensive and more detailed work in this area will show a series of major rhythms, of which these are only a part. In fact, observations in the North Quarry and in the Lukens and Yerkes quarry strongly suggest such a condition. It is hoped that more detailed field work can be carried out in the near future, and proof of these larger rhythms offered.

In the diagram in Figure 3 two stratigraphic sections are displayed. The left hand end of the lower column is a continuation of the right hand end of the upper column. The green coloring represents phyllite. The phyllite is taken to be the result of the metamorphism of clay sediments; each phyllite layer therefore represents a time when material differing from pure lime mud was being deposited. Much clay sediment implies that the water was not clear, and that either more land wash was coming into the sea, or else larger waves were stirring up the bottom muds and gradually working further seaward, or that both sets of conditions prevailed.

In the "Y" type of rock the phyllite and limestone succeed each other closely, the layers being so thin (1/8" or less) that it seems to suggest a climatic variation of a seasonal character. In the "Z" type of rock the paper-thin phyllite layers are separated by from 1/2" to 4" of limestone. This suggests longer time intervals separating the recurrence of the argillaceous sediment.

In addition to the rhythmic succession of phyllite layers we have another rhythm suggested by the recurrence of the different types of rock. The "A" type is a massive limestone, in most instances without visible evidence of phyllite. It seemed to contain a few phyllite layers at the extreme north end of the east face of Lazears and Yerkes quarry, but whether the layers really belonged to "A" or whether they were the beginning of another "Z" series which only showed at the surface was difficult to ascertain. In general, "A" seems to be barren of phyllite. In Figure 3 note the recurrence of "A" beds and the rapid alternation in at least two parts of the diagram, of the "Z" and "Y" beds.

These alternations constitute some of the major rhythms, the minor ones being the alternations of phyllite and limestone within the "Z" and "Y" beds.

As has been said above, conditions in the three quarries as a whole, suggest that there are still other major rhythms, and detailed microscopic study of the "Y" beds may result in the discovery of new minor rhythms within these layers.

It is the desire of the writer to carry out such investigations in the near future. At the present stages of these studies it would be unwise to endeavor to state the cause of these depositional rhythms in the Shenandoah limestone. Lack of fossils in the section under investigation makes it extremely difficult to trace any of the rhythms to an organic source, such as the life cycle of the cryptozoans mentioned in the first part of this paper. There remain the diastrophic and climatic hypotheses.

The writer suggests that the "Y" beds may owe their origin to variations in lime concentration causing deposition of pure lime muds followed by muds with a high clay content brought into the sea by streams, or else due to the periodic stirring up of the waters by storm waves. If the clay sediments were brought in by streams the added influx of fresh water would, in addition to bringing in clay sediment, lessen the lime concentration to some extent, and cause the formation of thin layers of a predominantly argillaceous composition. Climatic variation would of course be the underlying cause. The very thin laminae of the "Y" beds suggest that they might have sufficient time to accumulate during alternate wet and dry seasons of a year.

CONCLUSIONS.

Strong evidence of sedimentation rhythms is present in the Shenandoah limestone of the Ivy Rock district.

There is evidence of both major and minor rhythms.

It is not advisable, in most cases, to attempt to state the cause of these rhythms with the amount of data at present available concerning them.

A "diastem" or interval when no deposition was taking place, marks each change from limestone to phyllite. As there are many of these diastems present we may conclude that time required for the accumulation of the Shenandoah limestone in the Ivy Rock district was longer than for a limestone of this character without the phyllite layers. This factor has not heretofore been taken into consideration in connection with the time required for the formation of the Shenandoah limestone.

THE END.

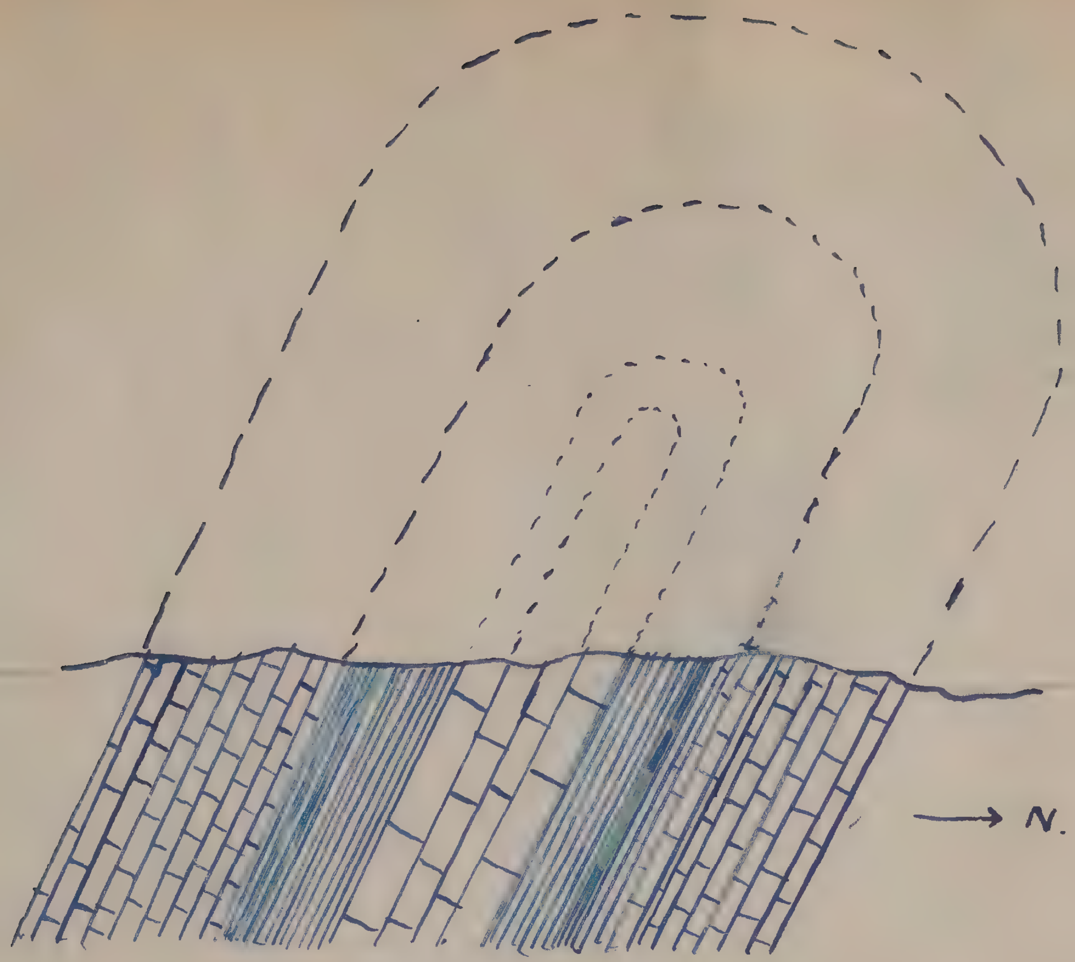
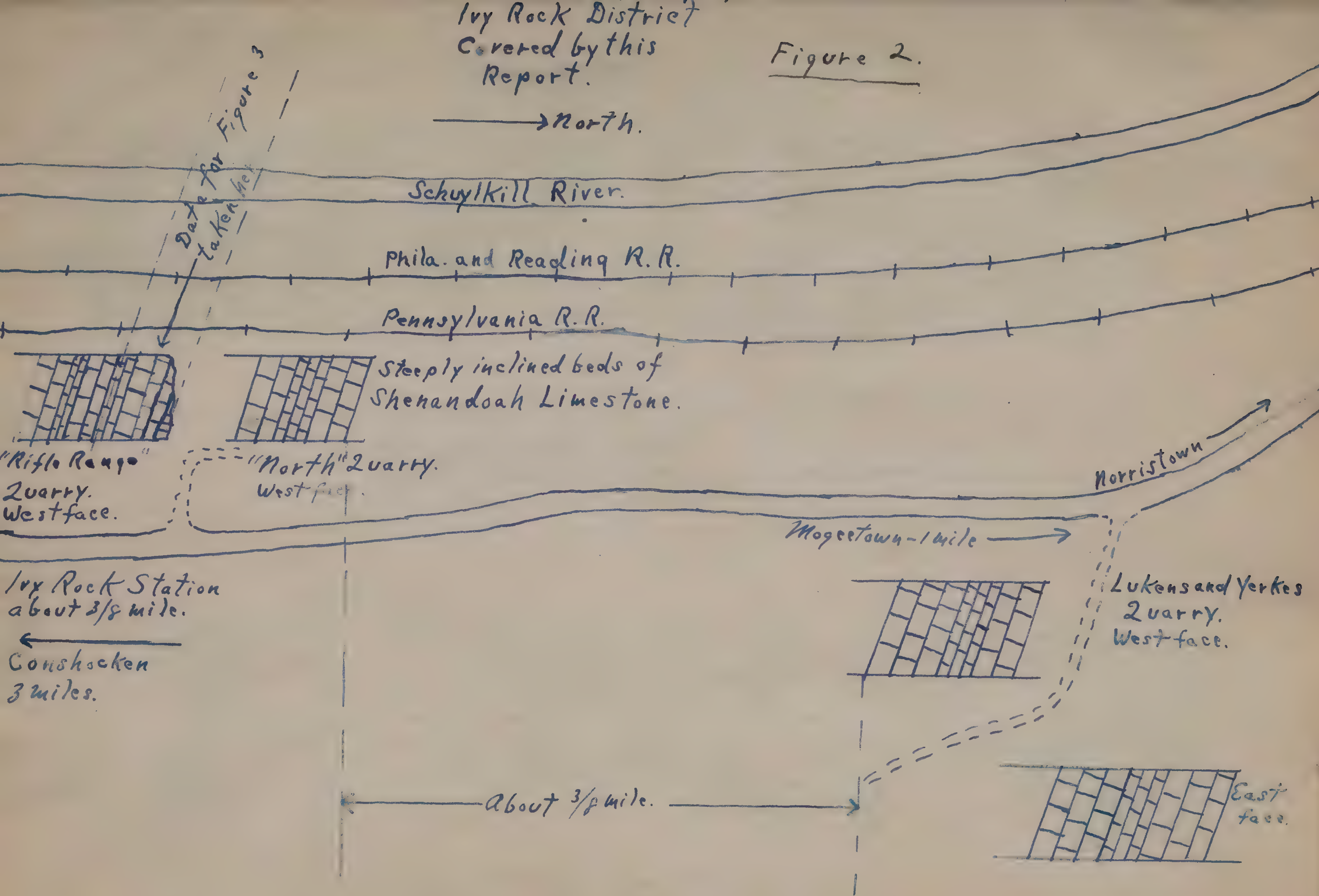


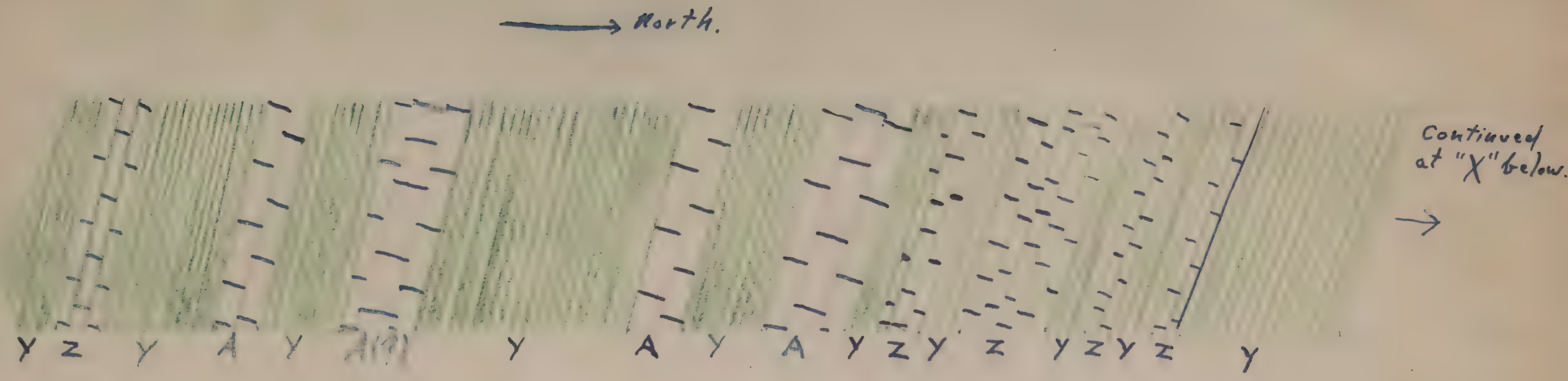
Figure I.

Isoclinal Fold in the north end of Rifle Range Quarry.

Shenandoah Limestone; near Ivy Rock, Pa.

Figure 2.


Ivy Rock District
Covered by this
Report.
North.
Data for Figure 3
taken here
Schuylkill River.
Phila. and Reading R.R.
Pennsylvania R.R.
Steeply inclined beds of
Shenandoah Limestone.
"Rifle Range"
Quarry.
Westface.
"North" Quarry.
West face.
Norristown
Mogeetown - 1 mile
Lukens and Yerkes
Quarry.
West face.
Ivy Rock Station
about 3/8 mile.
Conshocken
3 miles.
About 3/8 mile.
East
face.



For description of rock types A, Y, and Z, see text.
Green represents phyllite.
Sections shown here are taken from the north end of the west face of the "Rifle Range" Quarry. See Figure 2

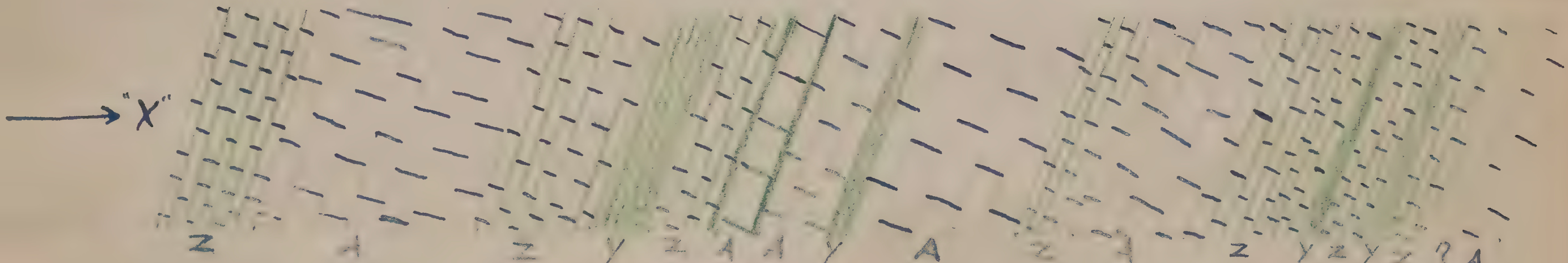


Figure 3.
Showing Rhythmic Deposition in the Shenandoah Limestone.